Investigation of Formation of Residual Nuclei from ^{nat}U by Reactions with 660-MeV Protons

J. Adam[1], K. Katovsky[2], R. Michel[3], A. Balabekyan[4], V. G. Kalinnikov[5], V. S. Pronskikh[6], A. A. Solnyshkin[5], V. I. Stegailov[5], V. M. Tsoupko-Sitnikov[5], S. G. Mashnik[7], R. E. Prael[7], K. K. Gudima[8]

[1] *Joint Institute for Nuclear Research, Dubna, 141 980 Russia; Institute for Nuclear Physics, The Academy of Science of the Czech Republic*
[2] *Joint Institute for Nuclear Research, Dubna, 141 980 Russia; Dept. of Nuclear Reactors, Czech Technical University, Prague, 180 00 Czech Republic*
[3] *Center for Radiation Protection and Radioecology, University Hannover, Germany*
[4] *Joint Institute for Nuclear Research, Dubna, 141 980 Russia; Yerevan State University, Republic of Armenia*
[5] *Joint Institute for Nuclear Research, Dubna, 141 980 Russia*
[6] *Joint Institute for Nuclear Research, Dubna, 141 980 Russia; St. Petersburg State Institute of Technology, St. Petersburg, 198 013 Russia*
[7] *Los Alamos National Laboratory, Los Alamos, New Mexico, 87545 U.S.A.*
[8] *Los Alamos National Laboratory, Los Alamos, New Mexico, 87545 U.S.A.; Institute of Applied Physics, Academy of Science of Moldova, Chisinau, Moldova*

Natural uranium targets were irradiated by a proton beam with energy 660-MeV in the Phasotron accelerator in Laboratory of Nuclear Problems in Joint Institute of Nuclear Research in Dubna, Russia. Cross-sections for the formation of residual nuclei were determined by gamma-spectrometry. Due to the large amount of residual nuclei they are divided (for processing purposes) into three half-life groups - long-lived (> 100 days), intermediate (100 days > $T_{1/2}$ > 1 days), and short-lived (< 1 day). The irradiation was performed in two parts - a short irradiation of one uranium target (5 min) and a longer irradiation of the second one (27 min) both with an intensity of approx. 2 μA. There was also third uranium target which was placed 30 cm perpendicular from the beam in the plane of the first and second targets and which was irradiated by background neutrons. The uranium targets had diameters of 15 mm weighted ca 164 mg. High quality HPGe detectors provided measurements of gamma rays. The measurement of the first uranium target started 12 min after irradiation to intent on measurement of short-lived nuclei; the second one was used to determine long-lived isotopes. To exactly monitor the beam the aluminum targets were used. Measurements of long-lived isotopes were carried out for two years. Total number of ca 150 spectra was analyzed; it means approximately 40,000 gamma lines to identify. Until now were successfully observed (with cross-section determination) ca 25 long-lived isotopes, ca 45 intermediate-lived isotopes, ca 120 short-lived isotopes and 11 isotopes from neutron induced reactions in the third (by background neutrons irradiated) target. Experimental results are compared with modern computation codes results. Until now were calculated theoretical predictions by codes CEM2k+GEM2, LAQGSM+GEM2, CEM2k+GEMINI, LAQGSM+GEMINI, INCL+ABLA. The final data will be also compared with theoretical simulation using codes those were developed within the HINDAS project.

Email: k.katovsky@sh.cvut.cz